



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

A Vector Error Correction Almost Ideal Demand Model for Organic Milk in the USA

Ye Su

University of Missouri
324 Mumford Hall
Columbia, MO 65211
ys4d8@mail.missouri.edu

Michael L. Cook

University of Missouri
125C Mumford Hall
Cookml@missouri.edu

***Selected Paper prepared for presentation at the 2015 Agricultural & Applied
Economics Association and Western Agricultural Economics Association Annual
Meeting, San Francisco, CA, July 26-28***

*Copyright 2015 by Ye Su, and Michael L. Cook. All rights reserved. Readers may make
verbatim copies of this document for noncommercial purposes by any means, provided
that this copyright notice appears on all such copies.*

Abstract

The objective of this study is to develop an econometric model for the demand analysis of organic and conventional milk in the USA by applying time series techniques. The results of the study can shed lights for policy making, marketing and production of organic and conventional dairy sections. The monthly aggregate organic and conventional fluid milk data from 2006 to 2013 are used for the analysis. A vector error correction almost ideal demand model with habit persistence is adopted to model the short and long run effects of consumer demand for milk. Price and expenditure endogeneity are also explored by introducing instrumental variables. The results show that the time series data are non-stationary at the level, but stationary at the first difference. The budget share, price and expenditure are cointegrated and the error correction terms are significant in the dynamic model. The prices are exogenous, but the group expenditure is endogenous. Therefore, the dynamic model with cointegration framework is a better model for the demand analysis. The price and expenditure elasticities estimated from three different models are compared and contrasted. The results show organic milk is more price elastic than conventional milk, but is still price inelastic. Organic milk is expenditure elastic, but the conventional milk is expenditure inelastic.

1 Introduction

The total organic food sales were \$35.9 billion in 2014, up 11% from 2013 (Organic Trade Association 2015). The organic dairy sales were \$5.46 billion in 2014 and 15.2% of the organic food sales, and also had 11% growth from previous year. The organic dairy is the second largest group after organic fruits and vegetables. Compared with conventional fluid milk, organic fluid milk sales have grown at a rate of more than 10% per year since 2006 vs. flat or declining conventional milk sales¹. There is little published work on organic milk demand and factors affecting the demand in the U.S. Current available studies use household survey or retail scanner data, which exclude away from home and school consumption. The household data representing one year cannot provide time varying variables such as income and consumer preference and taste. A few articles used retail scanner time-series data, but no studies considered time series properties (Chang et al. 2011, Li, Peterson, and Tian 2012).

The majority of studies in the U.S. about organic milk demand model use Nielsen homescan data. Two of them use the 2004 data (Alviola and Capps 2010, Chikasada 2008). The USDA National Organic Program was enforced in October 2002. As of 2004, organic milk consumers were still relatively new to the new labeling and regulation. Two national organic milk brands totaled 80% of the market share in 2004 (Dimitri and Venezia 2007). Since then, private label organic milk sales have been increasing dramatically². More than 100 local, regional, and store brands of organic milk have emerged³. Organic food is now

¹ Calculated with AMS-USDA, Federal Milk Market Order statistics, www.ams.usda.gov.

² http://www.nodpa.com/payprice_update_02062013.shtml

³ Organic Dairy Report - Cornucopia Institute, http://www.cornucopia.org/dairysurvey/Ratings_Alphabetical.html

sold in almost all of the traditional venues. The variety of organic milk also has increased. Flavored organic milk and DHA fortified organic milk are two examples. The market for organic milk is maturing. Consumers' preference and taste change along with the organic milk market. These factors can have profound effects on consumer purchasing behavior. The most recent data of organic milk demand studies are from 2010 (Li, Peterson, and Tian 2012). Therefore, it is necessary to provide an update on the status of consumer demand for organic milk. This study is aimed to fill this gap.

Three studies (Chang et al. 2011, Glaser and Thompson 2000, Li, Peterson, and Tian 2012) have used time series data to consider habit formation, but they have not considered time series properties and possible non-stationary property of the data. Although the ordinary least square (OLS) estimator of time series data is consistent, the inference of the estimation will be invalid if the data are not cointegrated. This is because the OLS technique requires that the error term are variance covariance stationary and autocovariance are finite and constant over time. Non-stationary time series data do not meet the requirements for OLS regression. Cointegration provides a framework for non-stationary time series data, which is explored in this study.

The objective of this study is to consider both long-run and short-run relationship among consumer demand, price, and expenditure and provide information for organic and conventional milk demand in the USA by using time series techniques. The article is organized as follows: section 2 and 3 introduce the almost ideal demand system (AIDS) and vector error correction (VEC) AIDS, section 4, 5, and 6 give introduction about the data, endogeneity of price and income, section 7 and 8 present time series analyses, section

9 provides the analysis of organic and conventional milk demand results, and the last section summarizes and concludes the paper.

2 Almost Ideal Demand System

Even though there are many demand models available, AIDS (Deaton and Muellbauer 1980) is the most popular one since it was published because it satisfies all the requirements of consumer theory. AIDS starts from a first order approximation of a cost function and derived through utility maximization. A few assumptions are made in the model: prices and income are exogenous, and the interested goods are weakly separable from other goods. Two-stage budget process is also assumed. In the first stage, the expenditure is assigned to different groups of goods. In the second stage, the expenditure is allocated within each group. The primary concern of this study focuses on the second stage. The AIDS is defined as follow:

$$w_{it} = a_i + \sum_{j=1}^n r_{ij} \log p_{jt} + \beta_i \log \left(\frac{x_t}{P_t} \right) + \varepsilon_{it}$$

$i, j = 1 \text{ to } n$ represent the number of interested goods in the model and equals three in this paper. Where w_{it} is the budget share of subcategory i in total milk expenditure at time t , a_i is intercept, p_{jt} is the price of j subcategory at time t . x_t is the total expenditure on the interested goods, P_t is a translog price index, and $\frac{x_t}{P_t}$ is considered as the real expenditure. β_i reflects the effect of real expenditure on budget share holding the price constant. Positive β_i means luxury goods and negative means necessary goods. The price index P_t is defined by the following formula and is nonlinear:

$$\log P_t = \sum_{i=1}^n \log P_{it} + 0.5 \sum_i \sum_j r_{ij} \log P_{it} \log P_{jt}$$

The nonlinear price index is difficult to estimate in empirical study. Deaton and Muellbauer proposed a linear approximate of the price index by using Stone Price index and is known as linear AIDS (LAIDS), where

$$\log P_t^* = \sum_{i=1}^n w_{it} \log P_{it}$$

In order to meet the choice theory, a few constraints need to be met. The adding up conditions are automatically satisfied if:

$$\sum_i a_i = 1, \sum_i r_{ij} = \sum_i \beta_i = 0$$

Homogeneity and symmetry conditions are imposed by satisfying the following constraints:

$$\sum_j r_{ij} = 0 \text{ and } r_{ij} = r_{ji}, \forall i, j \text{ } i \neq j$$

In practice, one of the equations is dropped in the estimation to meet the adding up constraint. This makes the homogeneity and adding up condition automatically met.

Uncompensated price elasticity for LAIDS is calculated by the formula:

$$\varepsilon_{ij}^M = -\delta_{ij} + \frac{r_{ij}}{w_i} - \beta_i \frac{w_j}{w_i},$$

δ_{ij} is the Kronecker delta =1 for $i=j$ and = 0 otherwise. w_i is the mean expenditure share across the sample for good i . Compensated price elasticity formula is:

$$\varepsilon_{ij}^H = \varepsilon_{ij}^M + \beta_i w_j = -\delta_{ij} + \frac{r_{ij}}{w_i} + w_j$$

Expenditure elasticity is calculated by this formula: $\eta_i = 1 + \left(\frac{\beta_i}{w_i}\right)$

3 Vector Error Correction (VEC) AIDS

The original AIDS model assumes that the error terms are uncorrelated and normally distributed. This assumption can be a problem in time series data because of the non-stationarity of the series, i.e., the covariance of a series changes over time. In fact, many time series data are first difference covariance stationary instead of level stationary. The first difference covariance stationary series is called integrated at order one, I(1) process. One popular method to regress non-stationary data is to use the first difference. However, if the time series are cointegrated, the simply first difference will misspecify the model. Two variables are cointegrated if each is an I(1) process but a linear combination of them is an I(0) process. For example:

$$y_t = a + x_t + \mu_t, \quad y_t \text{ and } x_t \text{ are I(1) processes}$$

$$\mu_t = y_t - a - x_t, \text{ if } \mu_t \text{ is a I(0) process, } y_t \text{ and } x_t \text{ are cointegrated.}$$

In addition, the regular AIDS model only considers the static aspect or long run relationship of the demand system. Vector Error Correction model (VECM) adds short run dynamic aspect to the long run equilibrium relationship. By including an error correction term in the model, VECM incorporates the mechanism of short run adjustment of consumption to move the short run disequilibrium back to the long run equilibrium. This model includes unit root test, cointegration test and then VECM modelling. There are a number of unit root test methods available. Augmented Dickey Fuller test (ADF) is used in this study. The estimated regression of ADF is specified as:

$$\Delta Y_t = \alpha + \delta t + \rho Y_{t-1} + \sum_{i=1}^p \varphi_i \Delta Y_{t-i} + u_i$$

Y_t is a random variable with no zero mean, α is constant, t is a time trend, and μ is the error term with iid $(0, \sigma^2)$ distribution. The null hypothesis is that the time series is non-stationary and $\rho = 1$. The alternative hypothesis is the time series is stationary. Under the null hypothesis, the test statistics has Dickey Fuller distribution. Non-stationary time series is differenced until they are stationary and the degree of integration is determined by the times of difference.

If the time series are integrated at the same degree, Johansens' maximum likelihood cointegration test is used to test the cointegration of the series. The cointegration represents the long term relationship among price, expenditure and budget share of the demand model. The null hypothesis is that the series are not cointegrated.

Traditional almost ideal demand system uses simultaneous price and expenditure data with budget share. This is considered as long term effects. In the long run, there is an equilibrium among price, expenditure and budget share. In the short run, due to asymmetric information, transaction costs, consumption pattern, and preference consistent, there is a period of adjustment of consumption to the price and income change, or there is a delay of adjustment to price and income change. The delay of adjustment makes the consumption deviate from the long run equilibrium. This is called short-run disequilibrium. The static model does not include the dynamic adjustment in the specification. The dynamic model solves this problem by including the short-run adjustment in the model using the vector error correction model (VECM). A vector error correction model is specified as:

$$\Delta Y_t = c + \alpha' \beta(Y_{t-1}) + \sum_j \phi_j \Delta Y_{t-j} + \varepsilon_t$$

β is the cointegrating vector, c is constant, α and \emptyset are coefficients. ε_t is the error term with identical and independent distribution. $\beta(Y_{t-1})$ is the error correction term and is estimated by the lagged residual of the OLS regression of the static demand equations. Due to the nonlinear property of AIDS, LAIDS is used in the VECM model. The VEC LAIDS is defined as:

$$\Delta w_i = \alpha + \delta' \vartheta(w_{it-1}) + \sum_i r_{ij} \Delta \ln p_j + \beta_i \Delta \log\left(\frac{x}{p^*}\right) + \varepsilon_i$$

Or

$$\Delta w_i = \alpha + \theta \Delta w_{it-k} + \delta'(\mu_{it-1}) + \sum_i r_{ij} \Delta \ln p_j + \beta_i \Delta \log\left(\frac{x}{p^*}\right) + \varepsilon_i$$

Lagged budget share is included in the dynamic equation to reflect the persistence of consumption habit and the delay of consumer response to the price and income change. The error correction term μ_{it-1} is a disequilibrium error from the long run equilibrium. The coefficient of the error correction term is expected to be negative and reflects the adjustment to return back to the long run relationship. The lower the coefficient, the slower the correction goes back to the long run equilibrium and the stronger is the habit effect. θ and δ represent short run dynamic of the demand system. The model is estimated using an iterated seemingly unrelated regression procedure in Stata version 13.

4 Data

This study focuses on organic and conventional fluid milk consumption in the U.S., because the majority of organic milk is consumed as fluid milk (about 70%). The data used in this study is aggregate monthly sales and price for organic milk as a whole and conventional whole and reduced fat milk (2%, 1%, and skim) over the period 2006-2013.

The reason for combining the organic milk as a whole is the prices of organic whole and organic reduced fat milk are almost the same in the studied period. The choice of milk is not affected by the price, but by the consumer preference. Totally there are 96 observations. The data are available from Agricultural Marketing Service (AMS) of the USDA. The monthly U.S. population data are downloaded from the U.S. Census Bureau. The per capita consumption data are calculated by the total sales divided by population. The prices are average across the U.S. The expenditure on each type of milk is calculated by the retail price multiplied by quantity consumed. The budget share is calculated by the expenditure on each goods divided by the total expenditure on all milk. The descriptive statistics of the data are provided in Table 1.

The descriptive statistics (Table 1) indicate that the price of organic milk is more than two times of the conventional milk in the studied period. The prices of conventional whole and reduced fat milk are close to each other (1.705, 1.693/half gallon). The consumption of organic milk is very low, only 3.3% of total fluid milk. The consumption of reduced fat conventional milk is the highest and is up to 68% of total milk consumption. Regarding to the budget share, organic milk is about 7% of total expenditure, while the conventional milk accounts for the rest 93%. The average total monthly milk consumption is 14 pounds (1.68 gallon; one gallon milk is equal to 8.6 pounds) per capita, which cost about six dollars on average.

Table 1. Descriptive Statistics of Conventional and Organic Milk Consumption

Variable	Description	Mean	Standard Deviation	Min	Max
p1	Price of conventional whole milk (dollar/half gallon)	1.705	0.137	1.489	1.980
p2	Price of conventional reduced fat milk (dollar/half gallon)	1.693	0.126	1.445	1.92
p3	Price of organic milk (dollar/half gallon)	3.877	0.300	3.41	4.7
v1	Conventional whole milk consumption (lbs./capita)	4.126	0.417	3.410	5.026
v2	Conventional reduced fat milk consumption (lbs./capita)	9.890	0.592	8.090	10.924
v3	Organic milk consumption (lbs./capita)	0.474	0.099	0.222	0.627
x1	Expenditure for conventional whole milk (dollar)	1.632	0.183	1.379	2.053
x2	Expenditure for conventional reduced fat milk (dollar)	3.890	0.347	3.222	4.699
x3	Expenditure for organic whole milk (dollar)	0.422	0.022	0.054	0.153
X	Expenditure for all milk (dollar)	5.945	0.500	5.105	7.178
w1	Budget share for conventional whole milk	0.274	0.019	0.243	0.327
w2	Budget share for conventional reduced fat milk	0.654	0.012	0.619	0.675
w3	Budget share for organic milk	0.071	0.012	0.041	0.092

lbs. = pound

The price of organic milk has an overall decreasing trend, but prices of conventional milk have slightly overall increasing trends (Figure 1). The log prices of conventional and organic milk appear non-stationary. But the first differences of the log prices look stationary. Figure 2 shows that the budget share of conventional whole milk has decreased, but the budget shares of conventional reduced fat and organic milk have increased from

2006 to 2013. These trends confirm to consumer preferences transforming from whole milk to reduced fat milk. According to Engle's law, goods with expenditure elasticity between zero and one will have decreasing budget share if the income rises, known as necessity goods. Luxury goods have expenditure elasticity over one and increasing budget share as income rises. The level data of budget share look like non-stationary in Figure 2, but the first differences appear to be stationary. This is the same for the log real expenditure on milk, non-stationary at the level, but stationary at the first difference (Figure 3). The real expenditure on all milk has an overall decreasing trend.

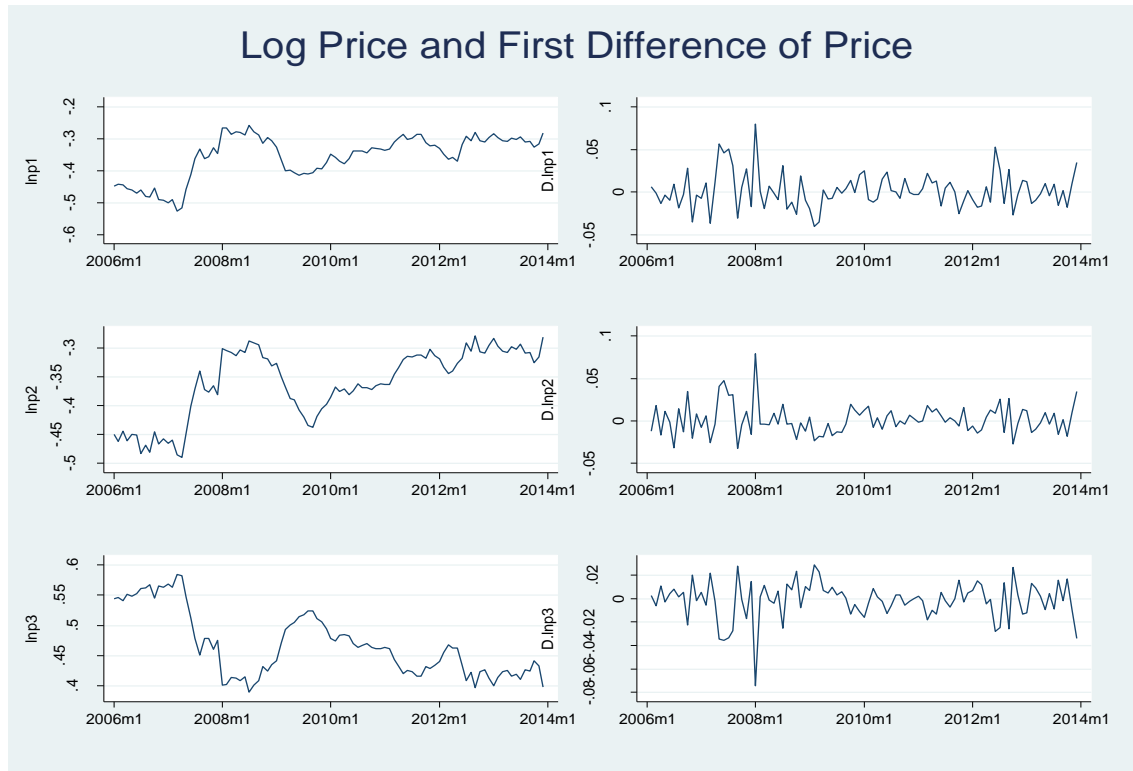


Figure 1 Log of retail prices of organic and conventional milk

Subscripts 1 is for conventional whole milk; 2 is for conventional reduced fat milk;
3 is for organic milk

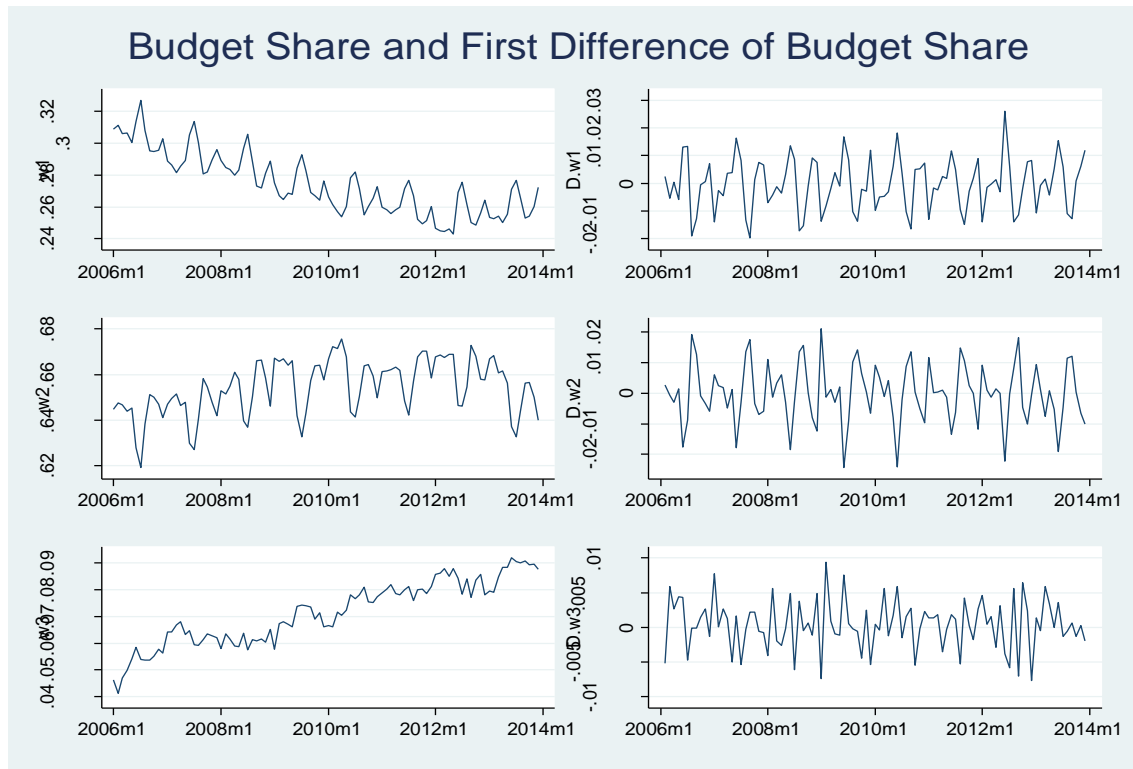


Figure 2 Budget shares of conventional and organic milk

Subscripts 1 is for conventional whole milk;
 2 is for conventional reduced fat milk;
 3 is for organic milk

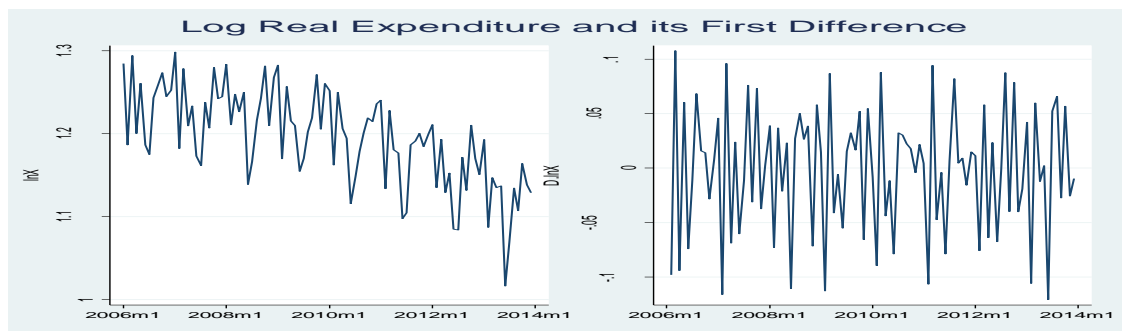


Figure 3 Log expenditure on all milk

Left is the level data and right is the first difference

5 Endogenous Prices

In the original AIDS model, prices and expenditure are assumed to be exogenous. Under certain cases, prices can be treated exogenous if the prices of interested products are relative rigid or stable and irresponsive to shocks (Duffy 2003). However, due to the aggregation of the data in this study, the price of each type of fluid milk could be correlated with the error term in the demand equation. Previous studies show that price under oligopoly market can be exogenous (Azzam 1999, Nakamura and Steinsson 2013). Stable price is an example of oligopoly market or imperfect market structure (Nakamura and Steinsson 2013). In the case of organic dairy market, there are only two national organic milk fluid milk manufacturers. So the market structure is a duopoly. Therefore, the retail price of organic milk could be exogenous. Though conventional milk has a well competitive market structure, the retail price of conventional milk is not competitive due to the oligopolistic power of retailers (Chidmi, Lopez, and Cotterill 2005, Carman and Sexton 2005). The retail price of conventional milk is relative stable and has a delay in responding to the change of farm price (Lass 2005). Therefore, the prices of the three type of fluid milk in the model could be exogenous due to the market structure and retailers' market power.

One way to correct the endogeneity is to use instrumental variable. This requires the instrument variable closely correlate with the endogenous variable, but uncorrelated with the dependent variable and the error term. One of the popular instrumental variables for the time series data is the lagged independent variable, which can be uncorrelated with error term. The other possible instrumental variable is to find a variable, which is correlated with

the endogenous variable but not with the dependent variable. The endogeneity can be tested with Hausman specification test. The Hausman test statistic is defined as:

$$H = (\theta^* - \theta)'(var(\theta^*) - var(\theta))(\theta^* - \theta)$$

The test statistic has a Chi square distribution with the degrees of freedom equal to the number of unknown parameters in θ . However, except the difficulty to find a correct instrumental variable highly correlating to endogenous variable but not to the dependent variable, another problem related to instrumental variable is weak instrument, where the instrumental is weakly correlated to endogenous variable. One way to measure the weak instrument is the F-statistics in first stage regression. If F-statistics is over 10, the instrumental variable is not considered as weak instrument (Wooldridge 2012). A few different instrument variables for price are chosen and the endogeneity is tested.

6 Endogeneity of Group Expenditure

In the original AIDS model, the expenditure is assumed to be exogenous. Under this case, the expenditure in the system is unrelated or unresponsive to the prices of interested goods. This could be a problem when the expenditure on group products is affected by the demand behavior, or some unobservable factors affecting both the expenditure and the consumer demand. The endogeneity of expenditure can lead to inconsistent and biased estimator (Thompson 2004, Dhar, Chavas, and Gould 2003, LaFrance 1991). To account the endogeneity of the expenditure, a few strategies have been attempted by researchers. The first one is to apply an instrumental variable, and the other is to include an explicit expenditure function. The first strategy is used in this study.

7 Unit Root Test Results

Augmented Dickey Fuller (ADF) test is used for the unit root test. Constant and trend are included in the test. The results show that all series are non-stationary at level but stationary at the first difference (Table 2 and Table 3). So the next step is to test the cointegration of the series with Johansen test.

Table 2 Unit Root Test Results for Budget Shares, Prices and Total Expenditure

Variables	Label	Test statistics	lag	p value	Unit root
Dependent variable					
w1	Budget share for conventional whole milk	-2.8	3	0.188	Yes
w2	Budget share for conventional reduced fat milk	-3.1	3	0.103	Yes
w3	budget share for organic milk	-3.05	2	0.117	Yes
Independent variable					
Lnp1	Log price of conventional whole milk	-2.23	2	0.471	Yes
Lnp2	Log price of conventional reduced fat milk	-2.36	2	0.398	Yes
Lnp3	Log price of organic milk	-2.75	1	0.214	Yes
LnX	Log expenditure of all milk	-2.33	2	0.417	Yes

The critical values are -4.055 for 1% and -3.457 for 5% and -3.154 for 10% significant levels with trend and constant.

Table 3 Unit Root Test Results for First Difference of Budget Share, Prices and Total Expenditure

Variables	Label	Test statistics	lag	p value	Unit root
Dependent variables					
Dw1	First difference of budget share for conventional whole milk	-7.70	4	0.0000	No
Dw2	First difference of budget share for conventional reduced fat milk	-9.33	2	0.0000	No
Dw3	First difference of budget share for organic milk	-8.29	1	0.0000	No
Independent variable					
DLnp1	First difference of log price of conventional whole milk	-5.14	1	0.0001	No
DLnp2	First difference of log price of conventional reduced fat milk	-4.31	1	0.0030	No
DLnp3	First difference of log price of organic milk	-5.63	1	0.0000	No
DLnX	First difference of log expenditure of all milk	-8.306	1	0.0000	No

The critical values are -4.055 for 1% and -3.457 for 5% and -3.154 for 10% significant levels with trend and constant.

8 Cointegration Test Results

The Lag selection procedure for the cointegration test is done by information criteria provided in Stata software. Three lags is selected for w1, 2 lags is selected for w2 and w3. The results are shown in Table 4. The results show that all three budget shares are cointegrated with log prices and log real expenditure with ranks one and two.

Table 4 Johansen Tests for Cointegration of Budget Share, Price and Expenditure for Demand Series

	lags	Rank	Eigen Value	Trace statistics	5% critical value
Without trend					
w1	3	1	0.42	67.76*	68.52
w2	2	1	0.43	25.86*	47.21
w3	2	2	0.33	31.45*	47.21
With trend					
w1	3	1	0.42	71.10*	77.74
w2	2	1	0.46	58.38*	68.52
w3	2	2	0.33	31.45*	47.21

*significant at 5% level

9 Empirical Results for Demand Model

9.1 Static Estimation

At first, the LAIDS model without constraints is estimated and the homogeneity and symmetry constraints are tested. The results are shown in Table 5. In this estimation, the conventional whole milk equation is dropped to meet the adding up constraint. The coefficients for conventional reduced fat milk are all significant at 5%, but the coefficients for organic milk are not significant. The coefficients of expenditure of conventional reduced fat milk is positive and significant at 1% level. Positive expenditure coefficient means conventional reduced fat milk is a luxury good. While the expenditure coefficients of conventional whole milk and organic milk are all negative.

Table 5 Estimated Parameters of Static LAIDS for the Milk Demand in the U.S.

	lnp1	lnp2	lnp3	lnX	Con	Trend
w1	-0.331	-0.608	-1.099	-0.130	0.642	-0.069
w2	0.286*	0.541**	0.924*	0.142**	0.336	0.026
t value	2.10	3.16	2.74	6.91	5.90	4.84
w3	0.045	0.067	0.175	-0.012	0.022	0.043
t value	0.80	0.94	1.25	-1.40	0.94	18.91

Without homogeneity and symmetry restricted. Equation one w1 is dropped in estimation
w1: budget share for conventional whole milk; w2: budget share for conventional reduced fat milk; w3: budget share for organic milk;

** significant at 1% level; * significant at 5% level

The homogeneity and symmetry of each demand equation are tested with Wald test. Homogeneity requires the sum of coefficients of all prices is equal to zero, i.e. $\sum_j r_{ij} = 0$. The Wald statistic has Chi square distribution with degree of freedom equal to the number of restrictions. The homogeneity condition represents the theory of absence of money illusion. The results in Table 6 show that only the organic milk demand equation meets the homogeneity constraint. The other two equations are rejected for the homogeneity in the static model.

Table 6 homogeneity and Symmetry Test of Static LAIDS of the U.S. Milk

	Homogeneity test	Symmetry test
w1 (<i>p</i>)	0.001	0.0016 (w1 w2)
Chi(2)	10.75	9.91
w2 (<i>p</i>)	0.005	0.017 (w2 w3)
Chi(2)	7.77	5.68
w3 (<i>p</i>)	0.27	0.001 (w1 w3)
Chi(2)	1.22	10.8

The LAIDS model with constraints are also estimated. The results are shown in Table 7. Comparing with the unrestricted model, the values of all coefficients decrease.

Only two parameters, organic milk price in organic milk budget share and real expenditure of reduced fat milk are statistically significant at the 5% level.

Table 7 Estimated Parameters of Static LAIDS for the Milk Demand in the U.S.

	lnp1	lnp2	lnp3	lnX	Con	Trend
w1	0.077	-		-0.139	0.484	-0.075
w2	-0.069	0.084		0.150**	0.472	0.032
t value	-1.43	1.54		7.07	5.80	6.18
w3	-0.007	-0.014	0.022**	-0.011	0.045	0.044
t value	-0.68	-0.36	4.24	-1.26	3.80	20.27

With homogeneity and symmetry restricted. Equation one is dropped for estimation

** significant at 1% level

9.2 Dynamic Estimation with Vector Error Correction Model

Time plays important factor in demand analysis since consumer preference, price and income (expenditure on milk) subject to change with time. The homogeneity and symmetry are rejected in the static model. Deaton and Muellbauer (1980) and Duffy (2003) state that the rejection of the constraints is due to the misspecification of a dynamic model in a static one. So, the next step is to build a dynamic model to incorporate long and short-run effects. In the dynamic model, two lagged budget shares are included to represent the habit persistence (the number of lags is determined by the information criteria in Stata). The error correction term is estimated from the lagged residual of OLS regression of the static demand system, because the coefficients of OLS are consistent. At the first, the unrestricted dynamic model is estimated and the results are shown in Table 8. The coefficients of lagged dependent variable and error correct term in conventional reduced fat milk and error correct term of organic milk are significant at 1% or 5% level in the unrestricted dynamic model. Both error correction terms of organic milk and conventional

reduced fat milk have the expected negative sign and significant at least at 5% level. Error correct term represents the short run consumption adjustment of consumer demand.

Table 8 Estimated Parameters of Unrestricted VECM LAIDS for the Milk Demand in the U.S.

	dlnp1	dlnp2	dlnp3	dlnX	L1dw	L2dw	EC
dw1	0.153	-0.246	-0.165	-0.073	-0.245	0.179	0.927
dw2	-0.217	0.175	-0.081	0.080	0.402	-0.182	-0.578
SE	0.161	0.163	0.355	0.012**	0.067**	0.072*	0.089**
t value	-1.34	1.07	-0.23	6.92	6.03	-2.51	-6.48
dw3	0.064	0.072	0.247	-0.007	-0.157	0.003	-0.348**
SE	0.070	0.071	0.152	0.005	0.088	0.078	0.090
t value	0.91	1.01	1.62	-1.46	-1.8	0.04	-3.88

d = first difference; L1 = one lag; L2 = 2 lags; EC = error correction term

*significant at 5% level; ** significant at 1% level

Then the homogeneity and symmetry are tested with Wald test for the dynamic model. All three budget share equations are homogenous. And the cross coefficients are symmetric in the system (Table 9). The results are very different from the results of the static model.

Table 9 Homogeneity and Symmetry Test of VECM-LAIDS of the U.S. milk

	Homogeneity test	Symmetry test
w1 (<i>p</i>)	0.2442	0.5023 (w1 w3)
Chi(2)	1.36	0.45
w2 (<i>p</i>)	0.6255	0.333 (w1 w2)
Chi(2)	0.24	0.94
w3 (<i>p</i>)	0.6746	0.6910 (w2 w3)
Chi(2)	0.18	0.16

The next step is to estimate a restricted model. In the restricted dynamic model (Table 10), most coefficients are significant at 5% level. This is a great improvement of the unrestricted model. The own price for conventional reduced fat and organic milk are significant at 5% level, but only the expenditure coefficients of conventional reduced fat

milk is significant at 1% level. The first lags of budget shares are significant. The error correction terms in organic milk and conventional reduced fat milk demand equations have expected negative sign and statistically significant. The conventional whole milk has positive sign for error correction term. This is due to the adding up constraints. The signs of the own prices in all three equations are as expected positive. Comparing with the static model, the own prices have the same sign, but the coefficients in the dynamic model are larger than the ones in the static model.

9.3 Dynamic Model with Instrument Variables

The lagged prices are first adopted as an instrument for endogenous prices. The Hausman-Wu test fails to reject the null hypothesis that three prices are exogenous. The partial R^2 of the lagged endogenous variables in the first stage regression is around 50%, and the partial F statistics is about 25 (F-statistics is over 10 for the standard). So this is not a weak instrument.

The second possible instrument variable for organic milk price is the price of organic feed, which is closely related to retail price, but not related to consumer demand. However, the data are not available. Therefore, the organic egg retail price is adopted for the organic milk price, because organic egg is a subsector of organic dairy. The Hausman-Wu test shows that the hypothesis that organic milk price is exogenous is rejected at 1% level. The F-statistic for the first stage is 15 and the first stage partial R^2 is 14%, which is relative small. The instrumental variable only weakly correlates with the endogenous variable. The instrument variables used for conventional milk are U.S. monthly feed corn price and sorghum price. However, these two instrumental variables have very low correlation with

the endogenous variables and are weak instruments. Weak instrumental variables also can lead to inconsistent and biased estimator. Based on the last two tests, the exogenous prices are assumed in the study.

In the test of endogeneity of group expenditure, the real disposable income is selected as an instrumental variable. The results show that the null hypothesis, the expenditure is exogenous is rejected, and the null hypothesis that instruments are weak also is rejected. The partial F-statistic is 22 and significant at 5% level. Therefore, the income deflated with price index is used as an instrument for group expenditure.

The right side of Table 10 shows the regression results of dynamic model with instrument variable for expenditure. In this model, almost all coefficients decreased from the left side dynamic model without instrument. One big difference from the model without instrument is that the signs of expenditure change to opposite. In the conventional reduced fat milk equation, the coefficient of expenditure changes from significant positive to insignificant negative. In the organic milk equation, the coefficient of expenditure changes from insignificant negative to significant positive. From this model organic milk is a luxury goods and conventional reduced fat is a necessary goods. This confirms with our perception. However, last month consumption difference has negative effect on budget share of organic milk but positive for conventional reduced fat milk. The coefficients of error correction terms in organic and conventional reduced fat milk have the expected negative sign, and have little change (-0.329 to -0.340) in organic milk equation from the model without instrument.

Table 10 Estimated Parameters of Restricted VECM LAIDS for the Milk Demand in the U.S.

	VECM-AIDS							VECM-AIDS with instrument						
	dlnp1	dlnp2	dlnp3	dlnX	L1dw	L2dw	EC	dlnp1	dlnp2	dlnp3	dlnX	L1dw	L2dw	EC
dw1	0.213	-0.186	-0.027	-0.072	-0.223	0.194	0.901	0.254	-0.215	-0.039	-0.017	-0.150	0.253	0.778
dw2	-0.186*	0.203**	-0.017	0.080**	0.404**	-0.183*	-0.572*	-0.215*	0.202*	0.014	-0.055	0.315**	-0.244*	-0.439**
SE	0.046	0.053	0.016	0.012	0.065	0.072	0.088	0.074	0.093	0.029	0.102	0.078	0.088	0.106
t value	-4.04	3.87	-1.03	6.92	6.22	-2.54	-6.52	-2.92	2.18	0.47	-0.54	4.05	-2.78	-4.16
dw3	-0.027*	-0.017	0.044**	-0.007	-0.181*	-0.011	-0.329*	-0.039	0.014	0.026*	0.073*	-0.165*	-0.009	-0.340**
SE	0.014	0.016	0.008	0.005	0.086	0.078	0.089	0.021	0.029	0.013	0.037	0.085	0.075	0.087*
t value	-1.96	-1.03	5.13	-1.5	-2.12	-0.14	-3.68	-1.86	0.47	2.02	1.93	-1.94	-0.13	-3.89

* Equation with w1 was dropped in estimation.

9.4 Elasticity

9.4.1 Price Elasticity from the Static Model

Price elasticities calculated with unconstrained static model do not have expected signs (not shown here). Therefore, the price and expenditure elasticities are calculated with coefficients from the restricted model. The uncompensated elasticities on the left of Table 11 for all three types of milk have expected negative signs. However, the elasticity of conventional reduced fat milk is even higher than the one of organic milk, which is not as expected. Both organic and conventional whole milk have elasticities less than one, but the conventional reduced fat milk has elasticity close to one. The cross price elasticity between conventional whole milk and conventional reduced milk shows that they are complements. Organic milk and reduced fat conventional milk are also complements.

Comparing with the uncompensated elasticity, the compensated elasticity (Table 12) of conventional reduced fat decreases significantly from -1.022 to -0.218, smaller than the elasticities of conventional whole milk and organic milk. The changes of elasticities of conventional whole and organic milk are small relative to conventional reduced fat milk. This is because of the large budget share of conventional reduced fat milk (the budget share in the formula of compensated elasticity). Organic milk has the largest compensated price elasticity, but still less than one and inelastic.

9.4.2 Price Elasticity from Dynamic Models

The uncompensated and compensated elasticities of all three goods in the dynamic model are shown in Table 11 and Table 12. The uncompensated price elasticities in the dynamic model without instrument are smaller than the values in the static model. The

dynamic model with instrument has largest absolute own price elasticity for organic milk -0.714 vs -0.382 and -0.628 in dynamic model with no instrument and static model. The own price elasticity of conventional reduced fat milk in dynamic model is the largest in all three models, but close to the value in the dynamic model with instrument. This is because the coefficients in the two dynamic models are close.

Regarding to the compensated price elasticities, the absolute values are smaller than the corresponding uncompensated elasticities in all three models. In the dynamic model, the consumption of conventional whole and reduced fat milk almost have no response to the price change (0.052, 0.037 elasticities for conventional whole and reduced fat milk respectively), and organic milk has somewhat response (-0.318 in dynamic with no instrument, and -0.517 in dynamic with instrument), but all elasticities are inelastic. In the dynamic models, three types of milk are complements, because the cross price elasticities are negative.

Table 11 Marshallian Uncompensated Elasticity of Milk from Three Models

	Static Model			VECM			VECM with instrument		
	p1	p2	p3	p1	p2	p3	p1	p2	p3
W1	-0.582*	0.078	0.009	-0.150	-0.507*	-0.079	-0.056	-0.744*	-0.138
SE	0.167	0.180	0.037	0.160	0.173	0.050	0.285	0.211	0.091
t value	-3.48	0.43	0.24	-0.94	-2.93	-1.58	-0.2	-3.52	-1.52
w2	-0.169*	-1.022**	-0.038*	-0.318**	-0.770**	-0.034	-0.306*	-0.636**	0.027
SE	0.075	0.084	0.017	0.070	0.082	0.025	0.143	0.099	0.053
t value	-2.24	-12.14	-2.19	-4.53	-9.36	-1.38	-2.13	-6.42	0.51
w3	-0.063	-0.103	-0.682**	-0.349	-0.164	-0.382*	-0.828*	-0.475	-0.714*
SE	0.147	0.174	0.063	0.193	0.233	0.119	0.392	0.288	0.207
t value	-0.43	-0.59	-10.8	-1.81	-0.7	-3.2	-2.11	-1.65	-3.45

All elasticities are calculated from restricted models with homogeneity and symmetry are imposed at the means of budget shares.

Table 12 Hickman Compensated Elasticity for Milk from Three Models

	Static model			VECM-AIDS			VECM with instrument		
	p1	p2	p3	p1	p2	p3	p1	p2	p3
w1	-0.446*	0.402*	0.044	0.052	-0.025	-0.027	0.201	-0.130	-0.071
SE	0.164	0.177	0.037	0.161	0.168	0.050	0.231	0.269	0.076
t value	-2.72	2.28	1.2	0.32	-0.15	-0.54	0.87	-0.49	-0.93
w2	0.169*	-0.218*	0.049*	-0.010	-0.036	0.046	-0.055	-0.037	0.092*
SE	0.074	0.083	0.017	0.071	0.080	0.025	0.113	0.141	0.044
t value	2.28	-2.63	2.85	-0.15	-0.44	1.87	-0.49	-0.26	2.08
w3	0.170	0.452*	-0.622**	-0.104	0.422	-0.318*	-0.274	0.844*	-0.571*
SE	0.141	0.159	0.063	0.193	0.226	0.119	0.294	0.406	0.177
t value	1.2	2.85	-9.9	-0.54	1.87	-2.67	-0.93	2.08	-3.22

All elasticities are calculated from restricted models with homogeneity and symmetry are imposed at the means of budget shares.

9.4.3 Expenditure Elasticity

The expenditure elasticities for all milk are significant at 1% level in all three models (Table 13). Conventional reduced fat has the highest expenditure elasticity and greater than one in the models of static and dynamic model without instrument. In the instrumented dynamic model, the organic milk is expenditure elastic and conventional milk has almost unit expenditure elasticity. For organic milk, 1% increase in total milk expenditure will increase organic milk consumption by 2%. This confirms organic milk is a luxury good.

Table 13 Estimated Expenditure Elasticities from Three Models

	Static model			VECM			Instrument VECM		
	w1	w2	w3	w1	w2	w3	w1	w2	w3
Elasticity	0.495	1.229	0.848	0.737	1.122	0.895	0.937	0.915	2.017
SE	0.077	0.032	0.119	0.039	0.018	0.070	0.303	0.157	0.526
t value	6.4	38.01	7.15	18.88	63.69	12.77	3.1	5.84	3.84

9.5 Habit Formation

There are different ways to model the dynamic time effect in a model. One of the methods is to use lagged consumption quantity in the model, and the other is to use lagged dependent variable, budget share. In the dynamic model, the coefficients of lagged budget shares of conventional reduced fat milk and organic milk are significant at the 5% level. In conventional reduced fat model, previous two periods consumptions have different effects on the current consumption. Immediate past consumption has positive effect on current effect, but consumption of two months ago has negative effect on current consumption. For

organic milk, consumptions in previous two months have negative effects on current consumption.

10 Summary and Conclusion

The objective of this study is to incorporate the time series property of the data and develop a VEC-LAIDS model for conventional whole, reduced fat milk and organic milk. This is the first paper to apply time series techniques in the demand analysis of organic milk. In addition, the study updates the organic milk consumption data to 2013, while most recent study was done with data in 2010 or before.

Organic milk consumption is still a small portion of the entire fluid milk consumption, 3% of volume and 7% of expenditure. The retail price of organic milk is two times of conventional milk. The consumption of the organic milk and reduced fat conventional milk have increased in the period, but the consumption of conventional whole milk has decreased.

The time series data are non-stationary and integrated at the degree one. The budget shares are cointegrated with log price and log expenditure. The estimated coefficients from the static and dynamic models have large differences, especially for the price elasticity. The results in both models show that conventional and organic milk are price inelastic, and the expenditure elasticities of conventional milk are close to unit, but organic milk could be up to 2.0 in the instrumented dynamic model. In the dynamic model, the demand of conventional milk is almost irresponsive to the price change. The dynamic model shows that the consumption pattern does affect the demand of milk or the persistence of consumption. Comparing with the static model, the dynamic model meets both

homogeneity and symmetry constraints, while the static model does not meet these constraints.

In both static and dynamic models, the compensated price elasticity has large difference from uncompensated elasticity. The results show organic milk has larger own price elasticity than conventional milk, but it is still inelastic, -0.714. This could be true to the committed organic milk consumers, or consumers who only consume organic milk. This elasticity is the lowest comparing with all current studies of organic milk demand (Alviola and Capps 2010, Chang et al. 2011, Choi, Wohlgenant, and Zheng 2013, Glaser and Thompson 2000, Li, Peterson, and Tian 2012, Chikasada 2008, Dhar and Foltz 2005). The closest elasticity is -0.802 in Chang (2011). The highest elasticity is -9.7 in Glaser and Thompson (2000), who found the price elasticity decreased with time. The most recent data set is from Li, Peterson and Tian (2012), in which supermarket weekly scanner data from 2008-2010 were used. In this study, the elasticities for organic milk with different fat contents are from -1.046 to -1.598, and organic whole milk has the lowest own price elasticity among all organic milk. However, time series property is not considered in this study.

The compensated own price elasticities of the conventional milk (-0.021 for conventional whole, and -0.037 for conventional reduced fat in dynamic model with instrument) are lower than the elasticities in all current studies. The low compensated elasticity means that with income compensated, the price has no effects on consumer demand of conventional milk. This is in line with consumption pattern of milk.

In the dynamic model without instrument, the expenditure elasticities of organic milk and conventional whole milk are inelastic, and the expenditure elasticity of conventional reduced fat is over one, 1.122. The expenditure elasticity of organic milk (0.895) is in the range of elasticities of current studies (from -8.6 to 0.871). This elasticity is close to the study of Li, Peterson and Tian (2012), 0.871, while the elasticity of organic milk in the dynamic model with instrument is 2.0 and elastic.

Demand analysis especially the price elasticity is important for the marketing and pricing strategy. Conventional and organic milk manufacturers and retailers can use the price elasticity information to direct their production, sales and marketing. Milk retailers also can use the price elasticity to set up their pricing strategy to increase their sales and revenue. Since organic milk is price inelastic overall for the aggregated data, retailers can increase the price of organic milk for high revenue as of conventional milk, especially when the consumers are committed organic milk drinkers. On the other hand, organic milk is expenditure elastic. High income consumers may purchase more organic milk than the consumers with relative lower income. Retailers may target their sales to different types of consumers for organic and conventional milk.

Other factors such as demographic variables, forecast and simulation need to be considered in the demand model. These will be investigated in the future research.

11 Reference

- Alviola, Pedro A., and Oral Capps. 2010. "Household demand analysis of organic and conventional fluid milk in the United States based on the 2004 Nielsen Homescan panel." *Agribusiness* 26 (3):369-388. doi: 10.1002/agr.20227.
- Azzam, Azzeddine M. 1999. "Asymmetry and rigidity in farm-retail price transmission." *American journal of agricultural economics* 81 (3):525-533.

- Carman, Hoy F, and Richard J Sexton. 2005. "Supermarket fluid milk pricing practices in the Western United States." *Agribusiness* 21 (4):509-530.
- Chang, Ching-Hsing, Neal H. Hooker, Eugene Jones, and Abdoul Sam. 2011. "Organic and conventional milk purchase behaviors in Central Ohio." *Agribusiness* 27 (3):311-326. doi: 10.1002/agr.20269.
- Chidmi, Benaissa, Rigoberto A Lopez, and Ronald W Cotterill. 2005. "Retail oligopoly power, dairy compact, and Boston milk prices." *Agribusiness* 21 (4):477-491.
- Chikasada, Mitsuko. 2008. "Three essays on demand for organic milk in the U.S., environment and economic growth in Japan, and life expectancy at birth and socio-economic factors in Japan." 3441052 Ph.D., The Pennsylvania State University.
- Choi, Hee-Jung, Michael K. Wohlgenant, and Xiaoyong Zheng. 2013. "Household-Level Welfare Effects of Organic Milk Introduction." *American Journal of Agricultural Economics* 95 (4):1009-1028.
- Davis, Christopher, Donald Blayney, Joseph Cooper, and Steven Yen. 2009. "An Analysis of Demand Elasticities for Fluid Milk Products in the US." International Association of Agricultural Economists Meeting, August.
- Deaton, Angus, and John Muellbauer. 1980. "An almost ideal demand system." *The American economic review* 70 (3):312-326.
- Dhar, Tirtha, Jean-Paul Chavas, and Brian W Gould. 2003. "An empirical assessment of endogeneity issues in demand analysis for differentiated products." *American Journal of Agricultural Economics* 85 (3):605-617.
- Dhar, Tirtha, and Jeremy D Foltz. 2005. "Milk by any other name... consumer benefits from labeled milk." *American Journal of Agricultural Economics* 87 (1):214-228.
- Dimitri, Carolyn, and Kathryn M. Venezia. 2007. "Retail and consumer aspects of the organic milk market [electronic resource] / Carolyn Dimitri and Kathryn M. Venezia." In.: [Washington, D.C.] : U.S. Dept. of Agriculture, Economic Research Service, [2007].
- Duffy, Martyn. 2003. "Advertising and food, drink and tobacco consumption in the United Kingdom: a dynamic demand system." *Agricultural Economics* 28 (1):51-70.
- Gardner, Bruce L. 1975. "The farm-retail price spread in a competitive food industry." *American Journal of Agricultural Economics* 57 (3):399-409.
- Glaser, Lewrene K, and Gary D Thompson. 2000. "Demand for organic and conventional beverage milk." Selected Paper presented at Annual Meeting of the Western Agricultural Economics Association, Vancouver, British Columbia.
- LaFrance, Jeffrey T. 1991. "When is expenditure" exogenous" in separable demand models?" *Western Journal of Agricultural Economics*:49-62.
- Lass, Daniel A. 2005. "Asymmetric response of retail milk prices in the northeast revisited." *Agribusiness* 21 (4):493-508.
- Li, Xianghong, H. H. Peterson, and Xia Tian. 2012. "U.S. consumer demand for organic fluid milk by fat content." *Journal of Food Distribution Research* 43 (1):50-58.
- Nakamura, Emi, and Jón Steinsson. 2013. Price rigidity: Microeconomic evidence and macroeconomic implications. National Bureau of Economic Research.
- Organic Trade Association. 2012. "Consumer-driven U.S. organic market surpasses \$31 billion in 2011." http://www.organicnewsroom.com/2012/04/us_consumerdriven_organic_market.html.

- Schrimper, Ronald A. 1995. "Subtleties Associated With Derived Demand Relationships." *Agricultural and Resource Economics Review* 24:241-246.
- Siemon, George L. 2010. "Organic Dairy Market also Hurt by Low Prices." *Rural Cooperatives* (January/February):15,-38.
- Thompson, Wyatt. 2004. "Using Elasticities from an Almost Ideal Demand System? Watch Out for Group Expenditure!" *American Journal of Agricultural Economics* 86 (4):1108-1116. doi: 10.1111/j.0002-9092.2004.00656.x.
- Wooldridge, Jeffrey. 2012. *Introductory econometrics: A modern approach*: Cengage Learning.
- Duffy, M. (2003). "On the estimation of an advertising-augmented, cointegrating demand system." *Economic Modelling* 20(1): 181-206.